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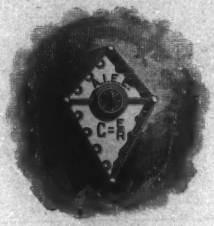

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A Paper presented at the 115th Meeting of the American Institute of Electrical Engineers, New York and Chicago, April 21, 1897.

THIS PAPER will be taken up for discussion at the meeting of May 18th.

[ADVANCE COPY—SUBJECT TO REVISION.]

THE SYNCHRONOGRAPH.

A New Method of Rapidly Transmitting Intelligence by the Alternating Current.

BY ALBERT CUSHING CREHORE AND GEORGE OWEN SQUIER.

Vol. 14
1897

In a general view of the technical history of the art of telegraphy, statistics show that at the present time, more than fifty years since the introduction of the telegraph, nine-tenths of the telegraph business of the world is transmitted by hand, in substantially the same manner as then. From an electrical point of view one naturally asks why it is, that during this period which represents more electrical progress than all time previous, the rapid transmission of intelligence has not made more advance.

It is to experiments upon a new electrical system of rapid intelligence transmission and its possibilities, that your attention and consideration are invited. It is not intended to enter into a discussion here of the physical causes which have limited the speed and efficiency of the telegraph, but to acknowledge the great work of Wheatstone, Hughes, Edison, Delany and others, who have brought rapid telegraphy to its present state of efficiency, and proceed to an explanation of the principles involved in the new system, and an account of the experiments already carried out in developing it. These experiments were conducted at the Electrical Laboratory of the United States Artillery School, Fort Monroe, Va., where the land telegraph and telephone lines were available for the actual trials described.

Principles of the Transmitter.

It is difficult to treat the subject of transmitters apart from their receivers, as any particular transmitter should be considered

in connection with the limitations of its receiving instrument. If we could have a receiver sensitive enough to make a distinct and permanent record of every change in current transmitted over the line, provided the line were so situated as to be free from the disturbing influences induced by external causes, it would be ideal; and the discussion of transmitters would be simplified by reducing the elements to the line and transmitting instrument alone. The qualities of receiving instruments include two principal elements. They all require a certain amount of energy to operate them, and in addition, most of them have inertia in the moving parts. A distinct advance is made, other things being equal, in the receiver which dispenses entirely with the inertia of moving parts. This is accomplished by electrolysis in the chemical receiver of Bain, which has recently reached great perfection in the hands of Mr. Delany. It is also accomplished in the polarizing receiver which was used in experiments described later.

Transmitters for sending intelligence over electrical circuits are, in every case, instruments which operate to change the strength of the current employed in the line. This includes the telephone, in which the current is a succession of waves differing not only in the frequency with which they occur, corresponding to the pitch of the tone, and in the amplitude corresponding to the loudness, but also as to the shape of the waves corresponding to the timbre or quality. The human ear is such a delicate and wonderfully constructed receiver, that it readily translates this complex wave into intelligence. If a physical instrument could be found which would write out in visible form the exact shape of these telephone waves received, the eye might also be educated to translate them. A perfectly trained eye could detect the difference between the same words spoken by different individuals as the ear now does. Even though the waves might be accurately reproduced, the simpler the waves the less the difficulty of translating them.

The inherent distinction between telephony and telegraphy is mainly that, whereas the telephone utilizes both the frequency of the waves and their form, telegraphy relies entirely upon the duration, number, and order of arrangement of these waves, and not their form. The art of telegraphy is practically limited in this respect to three elements, or their combinations, namely, varying the duration of the waves or pulses, the direction of them,

their order of arrangement, or the different combinations of these. Considering these elements separately, the first one, using waves of different duration alone for each character upon the line is not at present used. The last method, a combination of variable duration and order of arrangement of waves, comprises the system of Morse and others so universally used, and includes the more rapid system of machine telegraphy due to Wheatstone.

There are reasons why any system using waves of different duration is not as simple as one which uses waves of equal duration, when any arrangement of make-and-break transmitter, using a constant source of electromotive force is employed. Some of the chief of these are found in the electrical properties of the line carrying the currents. The difficulties become apparent only when it is attempted to send these waves at a very rapid rate, which is desirable in machine telegraphy. The current requires time to become established at the receiving end of the line after the electromotive force is introduced at the sending end. The current wave which is sent over the line is a function of the time during which the electromotive force remains applied at the transmitter. There is evidently a practical limit to the shortness of the time which the electromotive force must remain applied, determined by the smallest wave which the receiver is capable of recording.

Suppose on the other hand that the electromotive force has acted long enough for the current at the receiver to reach its steady value, and then the circuit is suddenly broken at the transmitter. A time will elapse before the current in the receiver is reduced to zero. This case is not as simple as the former, because the manner in which the break is made must be considered. A slow break is different from a rapid one, when there is any arc, that is, a spark formed. The whole line has been charged to the limit of the electromotive force used, and must become sufficiently discharged before the next wave can be received. This produces the effect commonly known as "tailing" which means that a signal becomes so drawn out at the receiver that it interferes with the following signal.

If waves of equal duration are used, evidently more of them may be received in a given time, than of any other combination of waves, for the shortest wave may be used which will operate the receiver. With this plan, the effect of "tailing" is reduced. The use of equal waves is adopted by Mr. Delany, who also indicates by the chemical receiver the directions, whether positive or negative, of these equal waves.

The alternating current is at present successfully employed for transmitting considerable amounts of power over long distances, and the whole system is periodically subjected to a regular and uniform succession of waves rising gradually from zero to a maxi-

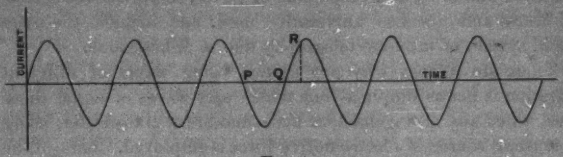


FIG. 1.

mum, and then gradually decreasing, reversing, and increasing to a negative maximum. Recognizing these facts, it seemed probable that it would constitute a good means for the rapid transmission of intelligence, if the characters of a telegraphic code could be impressed upon such a current without seriously affecting its regular operation. It is to the consideration of a system of rapid transmission of intelligence by the use of the alternating current that we invite your attention.

Let the sine curve, Fig. 1, represent a regular succession of simple harmonic current waves given to the line by an alternating current generator. If the current passes through a key which may be opened or closed at pleasure, then, provided the key previously closed is opened at a time corresponding to the point P of the wave upon the horizontal axis, it is known that the current which was zero at the instant the key was opened, will remain zero thereafter, in circuits which have resistance and inductance

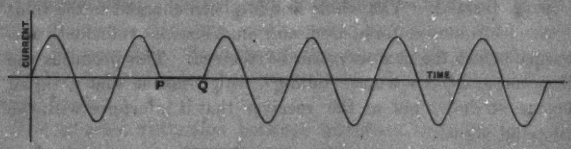


FIG. 2.

alone. Again, if the key could be closed exactly at a time corresponding to the point Q on the curve also upon the axis, the current will resume its flow undisturbed according to the sine curve. The true current obtained by opening the key at P and closing it at Q

is shown in Fig. 2, where the current remains zero between these two points. If the key had been closed at any other point than Q, as at R, the current would not have resumed its flow according to the simple sine wave; but, it can be shown, would follow the

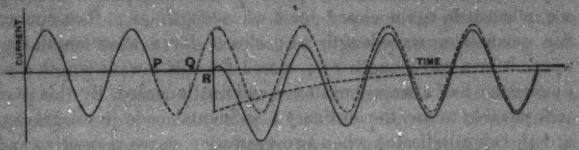


FIG. 3.

heavy curve of Fig. 3, and give a succession of waves alternately smaller and larger than the normal sine wave until after a very few alternations, when it practically coincides with the sine wave. In like manner if the key is opened at some other point than P, when therefore the current is not zero, a spark may be observed at the break, and it requires time for the current to fall to zero.

Let us consider the advantages of thus operating upon an alternating current. It is evident that the advantages above mentioned of using a system subjected to a perfectly regular alternating electromotive force, and capable if necessary of transmitting considerable amounts of power, is by this method made available. In addition, no spark is made in a transmitter adjusted to break the circuit at the exact times indicated by the curve above, when the current is naturally zero. This makes it possible, if it is found desirable, to use comparatively large electromotive forces and currents on the line, for no matter what the maximum value of

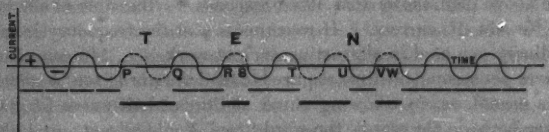


FIG. 4.

the current, it is made and broken by this plan with no sparking. It is also possible to employ waves of high frequency upon the line, the upper limit obtainable from an alternator being probably much higher than can be transmitted over the line.

If a receiver were used which could reproduce an exact trace of the actual waves sent over the line, it might resemble such a combination as that represented by the heavy curve in Fig. 4. The sine wave continues uninterrupted to the point P when the key is opened, and it is held open for one complete wave-length P Q, when it is again closed for a wave-length Q R; then opened for one-half a wave-length R S; closed for a wave-length S T; opened for a wave-length T U; closed for half a wave-length U V; opened for half a wave-length V W and finally closed. By this plan it is possible to use the ordinary Continental code in telegraphy, a dash being indicated when two successive waves, a positive and a negative one, are omitted by keeping the key open, and a dot meaning where a single half-wave is omitted. The space between parts of a letter, as between the dash and dot of the letter "n" is indicated by the presence of one-half a wave-length, and the space between letters, as between "t" and "e" in the word "ten," by the presence of two half-waves, while the space between words may be represented by the presence of three half-waves, and between sentences of four half-waves or more. The above is a single example, of which there are many, of a method by which the usefulness of so operating upon an alternating current is made apparent, because it shows how these signals may be interpreted by a fixed code. It need not be said that there are other ways easily devised of interpreting the possible combinations of waves which may be sent in accordance with any code, and it is not our present object to present a method which is deemed superior to others, but merely to show that the above plan becomes operative.

A consideration of the time required to send the word "ten" by the above plan shows that it corresponds to the time of eleven half-waves of current. If we suppose that the frequency is an ordinary one used in alternating current work, viz., 140 complete waves per second, the time required to send the word "ten" is .0394 of a second, or, by allowing three additional half-waves for the space between the words, the word "ten" would be sent just 1200 times in one minute. There is no difficulty in using over some lines, a frequency four times as great as that ordinarily used, namely, as high as 560 or even 600 periods per second. This would correspond to speeds of 4800 and 5143 times sending the word "ten" per minute. The limit in each instance is only determined by the particular line used.

Hitherto it has not been pointed out how it is possible to manipulate a key at the high speed mentioned, so as to open and close the circuit hundreds of times per second as desired at the exact instants when the current is naturally zero. Evidently the proper place to manipulate such a current controller where the circuit must be made and broken at distinct points of phase, is at the generator itself, or in connection with any motor running synchronously therewith.

It will be sufficient for purposes of illustration to show by a special example how any single half-wave may thus be controlled at the generator; for obviously any word or sentence may be formed by a repetition of this operation.

In Fig. 5, S represents the shaft of an ordinary 10-pole alternating current generator which drives through the gears M and N, the wheel W. The circumference of this wheel is one continuous

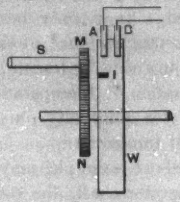


FIG. 5.

conductor presenting a smooth surface for brushes to bear upon. If the periphery of the wheel is divided for example into 40 equal parts, and it is geared to run at one-fourth the speed of the armature, each division thereof corresponds to one semicycle of the electromotive force produced by the generator. Upon the wheel W bear two brushes A and B carried by a brush-holder which is capable of adjustment. These two brushes are connected in series with the line, so that the current which passes in at one brush, is conducted through the wheel to the other brush, and thence to the line. The current used may be obtained from the generator, the shaft of which is represented at S, either before or after it has passed through any number of transformers, since it is the frequency alone with which we are concerned.

The line current is brought to the wheel W to be synchronously operated upon. If both brushes remain continually in contact with the wheel, the current transmitted would have the regular

sine form represented in Fig. 1, and for each revolution of the wheel there would be 40 semi-waves or 20 complete waves transmitted. If one-fortieth of the circumference of the wheel is covered by paper or other insulating material as indicated at 1 Fig. 5, and the brush A adjusted to ride on to and off from this insulation just as the current is changing from one semicycle to the next, that is, changing sign, while the brush B is in continuous engagement with the wheel, the semicycle represented by the section covered will be suppressed, and without any sparking, even if the potential used is high. In practice, the brush A is easily adjusted to this point by moving it slightly, backward or forward around the circumference of the wheel until the sparking ceases. This adjustment once made, the brush is fixed in position and so remains. In each succeeding revolution of the wheel, this cycle of operations is exactly repeated, and the current sent over the line would resemble that shown in Fig. 2, having every fortieth semicycle omitted. It is only necessary to cover other similar sections of the circumference of the wheel in a predetermined order according to a code, to transmit intelligence over the line. The above illustration of the operation of a transmitter on this principle is given for simplicity only, and is evidently far from a practical form of transmitter.

The wheel w in the above example, may have different speeds with respect to the generator shaft, the essential condition being that its circumference shall contain some integer number of a unit, which is the arc upon the circumference of the wheel if geared to the armature, that a point fixed with respect to the field would describe upon it during one semi-period of the current. This wheel therefore might be connected to any shaft which runs in synchronism with that of the generator, as for instance that of a synchronous motor if the power were obtained from a distance.

Instead of using insulating papers situated upon a single circumference of the wheel, two or more similar lines may be used either upon different circumferences of the same wheel or upon different wheels, and separate brushes ride upon the different circumferences. The same frequencies of current may be employed to operate all lines of brushes, or currents having different frequencies may be employed upon the separate circuits, all of which use the same line for transmission. These arrangements make it possible either to send different messages simultaneously over the same line employing a single cycle as the unit, or to send

a message employing different frequencies to represent the different characters of a code, or many combinations of these.

The employment of alternating waves of different frequencies upon the same line by the method shown, does not have the same objections which exist when a constant electromotive force is used. Since the circuit is by this system always interrupted when the current is naturally zero, the frequency employed is within certain limits a matter of indifference as the line is in the same condition whether a long or a short wave is used.

It is seen that by this simple method of operating upon the alternating current, according to the above principles, there is complete control of the individual semi-waves of the current, which may be changing direction thousands of times in a second, far beyond the range of possible manipulation by hand. In other words it is easy to obtain a record of any pre-selected order or succession of semi-waves desired. It is evident that it is as important to be able to control the semi-waves retained, as it is those suppressed, since they are of equal value in interpretation. Furthermore there is great utility in being able to control *each single semi-wave* of the current, for this permits the maximum speed of transmission of signals with a given frequency.

A transmitter which operates upon the current at intervals comparable with the duration of a semi-wave, but which does *not* act in synchronism with the current, would necessarily make and break the circuit at times when the current is not naturally zero. If this were done there would not only be sparking, but in addition, the current would be interfered with in such a manner as to make it probable that the record received could not be interpreted; for the current at each make would follow such a curve as that shown in Fig. 3.

Principles of Receivers.

As used throughout this paper, the term "receivor" will be understood to mean that mechanism which uses the energy transmitted over an electric circuit, and transforms it so as to make a permanent record which may be translated into intelligence. The term receiver is here restricted to mean instruments which make a permanent record, since this is a necessary condition for the rapid transmission of intelligence, with which we are at present concerned. All receivers require a certain amount of

power to operate them, and the power required affords one basis for their classification.

Another method divides receivers into two classes, those which have inertia in the moving parts and those which have none. There is no fundamental reason why any one of these general classes should contain all of the most rapid receivers. Any of the above classes might include receivers which are very rapid. If, for instance, a receiver has inertia in the moving parts, for rapidity the amount of inertia should be small, and its natural period high, or a large amount of energy would be required to operate it. If a receiver has no inertia in the recording mechanism, then the possible rapidity is limited by the power supplied.

In deciding upon the relative merits of receivers from the point of view of rapidity, the cost of the power required offers no reason why considerable amounts of power should not be transmitted over certain land lines for purposes of telegraphy. Using a receiver which possesses much inertia in its moving parts, it does not follow that even though considerable energy reaches the receiver over the line, that it will be rapid in its action.

The Wheatstone receiver may be taken as representative of a type of receivers possessing inertia in the moving parts, which has come into successful operation. The record is made in this instrument by a small wheel which vibrates back and forth between an ink surface and the recording tape. The energy which is essential, is that required to move this little wheel and the parts connected with it back and forth. Although considerable energy may possibly be sent over the line and be expended in the instrument, it seems impossible to concentrate more than a certain part of it upon the moving mechanism. This suggests two methods of improving the speed of the system; either to increase the power received by the moving parts, or diminish their moment of inertia. One factor which limits the Wheatstone type of receiver is that the moving parts are required to do the work of making the record. This is not a necessity, since light may be employed as the agent to make the record under the control of the moving parts, as is evidently accomplished in a form of galvanometer having a very minute needle with mirror attached, the slightest motion of which is greatly magnified by the reflected beam of light.

As a type of instrument having no inertia in the recording mechanism, may be mentioned the various forms of chemical

receivers acting by electrolysis. This type of receivers possesses many advantages, perhaps chief among which is the fact that a large part of the energy received is brought directly to bear upon making the record. Another feature is the simplicity of the essential mechanism involved, as no intermediate steps are employed after the impulse is received from the line before the record is made. These qualities alone imply rapidity, and this receiver is one of the most rapid known. The limit of rapidity with this receiver is the power received from the line. If the potential between the terminals of the receiver is increased, the time required to make a given record is correspondingly reduced. The use of the alternating current permits of greater potentials being realized in the receiver with less disturbing influence from the line than would be the case if a constant direct electromotive force was employed.

A new type of receiver having no inertia in the recording mechanism was used in developing the transmitter described in these experiments. This instrument has already proved of value as a chronograph for the measurement of minute intervals of time, and for the study of any kind of variable electric currents. Although its application as a practical telegraph receiver is not at present advocated, yet the realization of a *massless* receiver upon different lines merits description. This receiver is based upon Faraday's discovery of a direct relation between light and electricity.

This discovery was, that if a beam of polarized light is passed through some substance in the direction of the lines of magnetization within that substance, there is a rotation of the plane of polarization in a direction which is the same as the direction of the current required to produce such a magnetic field. The direction of rotation is unaltered, therefore, whether the light beam advances in the same or in the opposite direction to the magnetization, so that a beam reflected back and forth through the substance several times, has its rotation increased by equal amounts each time. If the direction of the ray of light is at right angles to the lines of magnetization, there is no rotation produced. The amount of this rotation has been investigated by Verdet, who announced laws by which it may be expressed. They are summed up in the following statement:

"The rotation of the plane of polarization for monochromatic "light is in any given substance proportional to the difference in

"magnetic potential between the points of entrance and emergence "of the ray"; that is, it is equal to a constant times this difference of potential and is expressed by the formula

$$\theta = v\ V,$$

where θ = angle of rotation, V = difference in magnetic potential, and v for a given wave-length is constant in any one substance and is known as Verdet's constant.

The following example will make more evident the application of Faraday's discovery to this receiver. Admit a beam of ordinary light through a small aperture into a dark room and let it fall upon a white screen. Suppose that the aperture which admits the beam is provided with a shutter which may be opened or closed at will. We have in this simple arrangement all the essentials of a transmitter and receiver of intelligence. A person opening and closing the shutter might communicate with a second person observing the screen, which would become light and dark at intervals in accordance with a pre-arranged code. Substitute for the first person in direct control of the shutter an electromagnetic device, operated from any desired distance through an electric circuit, and the effect upon the screen is the same as before. For rapid transmission it would be necessary to substitute a mechanical transmitter which would operate faster than a person can send by hand. There would be no particular difficulty in thus moving the shutter more rapidly than any observer could read from the screen. It then becomes necessary to make a permanent record, which may be accomplished by substituting for the screen a self-recording surface having a relative motion across the beam. This is afforded by using any surface sufficiently sensitive to light, many varieties of which are available. In fact a surface is available which is so sensitive that it will record much faster than the *material shutter* can be moved back and forth so as to open and close the aperture.

The next step in increasing the speed, provided the limits of the transmitter have not already been reached, is to secure a more rapid shutter. It was with this object in view, to obtain a *massless shutter* that Faraday's discovery is used. Instead of passing the light directly through the aperture, it is first passed through a Nicol prism in order to obtain a beam of plane polarized light, or it may be polarized in any other suitable manner. Suppose that a second Nicol prism like the first is placed in the path of

the polarized beam. If the second prism known as the "analyzer" is turned so that its plane is perpendicular to that of the first prism known as the "polarizer," all the vibrations not sorted out by the polarizer will be by the analyzer. In this position when the planes are perpendicular to each other, the prisms are said to be "crossed." and an observer looking through the analyzer finds the light totally extinguished as though a shutter interrupted the beam. By turning the analyzer ever so little from the crossed position, light passes through it, and its intensity increases until the planes of the prisms are parallel, and if one of the prisms is rotated, there will be darkness twice every revolution. In order to accomplish the same end that is obtained by rotating the analyzer without actually doing so, the following plan is adopted: Between the polarizer and the analyzer is placed a transparent medium which can rotate the plane of polarization of the light, subject to the control of an electric current, without moving any material thing. The medium used in this receiver is liquid carbon bisulphide contained in a glass tube with plane glass ends. There are many other substances which will answer the purpose, some better than others. This was selected because it is very clear and colorless, and possesses the necessary rotatory property to a considerable extent. It only possesses this property, however, when situated in a magnetic field of force, and the rotatory power is proportional to the intensity of the magnetic field. To produce a magnetic field in the carbon bisulphide, a coil of wire in series with the line from the transmitter is wound around the glass tube. When the current ceases, the carbon bisulphide instantly loses its rotatory power. The operation is as follows: First the polarizer and analyzer are permanently set in the crossed position, so that no light emerges from the analyzer. A current is sent through the coil around the tube. The plane of polarization is immediately rotated. This is equivalent to rotating the polarizer through a certain angle, and hence light now emerges from the analyzer. Interrupt the current, the medium loses its rotatory power, and there is again complete darkness. The arrangement makes an effectual shutter for the beam without moving any mass of matter.

This illustrates how Faraday's discovery may be utilized to replace the electromagnetic shutter in the above example by a massless shutter, which enables the current waves sent over the line to be recorded upon the sensitive surface without moving any material thing. An advantage of this receiver is that the

speed is not limited by the receiver but only by the natural properties of the line or of the transmitter. Used in connection with the transmitter already described, the real limit is found to be in the line itself.

An analysis of this receiver shows that the energy received over the line is not used directly in making the record, but the agent which makes the record is the beam of light which derives its energy from a local source. The energy received from the line merely controls this local energy which may have considerable power behind it. This controlling phenomenon is one of the few known cases where electricity acts directly upon light. The mechanism by which this action is effected is not at present known, and any experimental evidence upon it would increase our knowledge of the connection between ether and ordinary matter, as well as the constitution of matter itself. The use of this direct influence of electricity on light makes the speed of transmission through the receiver comparable with the velocities of these agents.

Description of the Transmitter Used.

In these experiments, the operation upon the alternating current according to the principles already stated, was accomplished by means of a prepared perforated paper tape, which was caused to move by the generator itself. A view of this tape, showing a method of operating upon the current is given in Fig. 6.

The line current is brought through the wires W W to two brushes B B′ not shown in the view, held by the adjustable support S. The plan of the brushes is shown in Fig. 7. One brush B bears upon the tape from above, and the other brush B′ bears from below immediately opposite the other brush so that they will meet through the perforations in the transmitting tape T. When the brushes meet through the perforations in the tape, the line circuit is closed, and when paper passes between them, separating the brushes, the line circuit is broken.

It is so arranged that the brushes pass off from, and on to the paper, thus making and breaking the circuit, at the instant corresponding to the points in the current wave, Fig. 1, when the alternating current is naturally zero. The tape T passes over a wheel P geared to the generator shaft, so that for one revolution of the armature, the tape advances a fixed distance. If the gen-

erator has ten poles, this fixed distance on the tape corresponds to five complete waves or ten alternations or semi-cycles of the generator current. One-tenth of this fixed distance corresponds to one alternation or semi-cycle of the current, and may be taken as the unit of distance in perforating the tape. If therefore a hole is made in the tape equal in length to this unit, and the brushes B and B′ happen to pass off from the paper so as to meet through the hole at the instant the current is naturally zero, then they will pass on to the paper again, breaking the circuit at the next following instant when the current is also naturally zero, since the length of the hole corresponds to one semi-cycle of the current.

Suppose that a succession of these unit holes is made, the tape between the holes being also of unit length, then the circuit will be made and broken as by the first hole at the points of zero current. In practice it would probably not happen that the brushes were at first so situated as to pass off from and on to the paper at

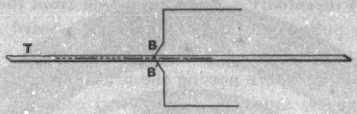


Fig. 7.

the instant the current is zero. In this case a succession of sparks appears, one each time the brushes pass on to the tape, and by moving the brushes along the tape it will be observed that this spark either increases or decreases in intensity, according to the direction moved; but at regular intervals, equal to the unit mentioned above, it disappears. This position of the brushes for no sparking is easily found by trial, and once obtained remains fixed. By this simple practical operation which experience shows requires but a moment to accomplish, the essential condition of synchronously operating upon the current in the manner described is secured. The brushes once adjusted always so remain, and since there is no sparking, it is possible to use high electromotive forces upon the line without injurious effect upon the brushes and tape. It is also plain that this method of operating upon the current is not affected by the speed of the generator, since the transmitting device is always in synchronism with the generator,

whatever the speed. The speed of the generator, and consequently the rate of sending, as far as the transmitter is concerned, can be varied at pleasure between wide limits, without any effect upon the synchronous operation described.

An example, giving the data from an early experiment, will illustrate how this is accomplished. The generator was a Fort Wayne 10-pole alternator giving a potential at its terminals of 1,000 volts. This was transformed to about 300 volts, being convenient to handle, and sufficiently high for the purpose. The end of the shaft E, Fig. 6, of the generator carries a small pinion, which engages the gearing G, and revolves the wheel P once in every 18.4 revolutions of the armature. This makes the $\frac{1}{184}$ part of the circumference of the wheel P correspond to one semi-cycle of the current. The circumference of the wheel was about 100 cms., and the length of a unit, therefore, $\frac{1}{184}$ of this, or .54 cms.

For convenience, a tape made of ordinary paper, had its two ends joined so as to make a continuous belt, which made it possible to use it repeatedly. The tape passed from the large wheel P to the loose pulley Q mounted upon a base-board A, and under the guiding pulley attached to the support S which controlled the tape, immediately before passing the brushes B B'.

In preparing the tape, the Continental code was employed as described, the omission of two half-waves meaning a dash, and one half-wave a dot. Having obtained the length of a unit on the wheel, the tape is first divided into these equal units, and then the proper units are cut out to form a message. The units which are not cut out form the dots and dashes. To use a continuous tape it is necessary for its length to be some exact multiple of the unit, in order that it may start on the second revolution exactly as it did the first.

The generator current of high potential passed directly through the primary of a transformer, and the secondary was used as the source of electromotive force for the line. This secondary circuit which includes the line was brought to the transmitter to be operated upon as described.

A diagram of the electric circuits as employed in this experiment is shown in Fig. 8, where A represents the alternator, T the transformer, B the brush bearing upon the transmitting wheel W, and L the line. Another diagram illustrating how the method may be used with currents of the same or different frequencies,

FIG. 6.

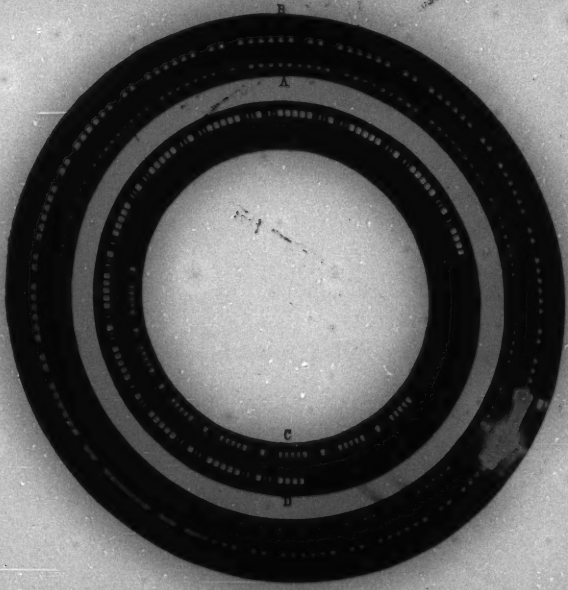


FIG. 10.

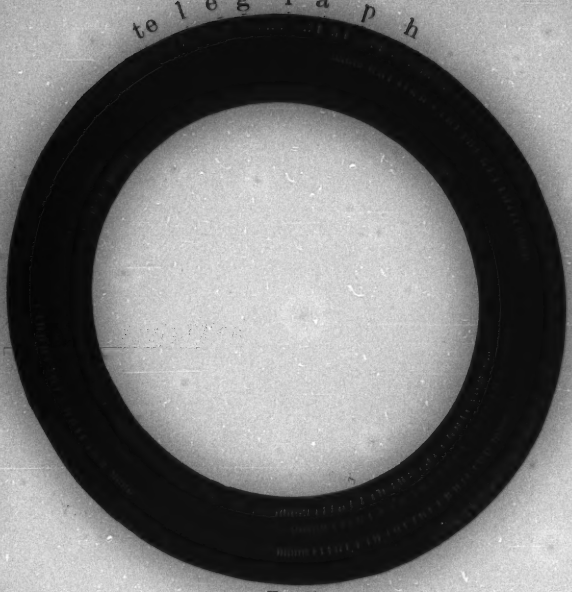


FIG. 11.

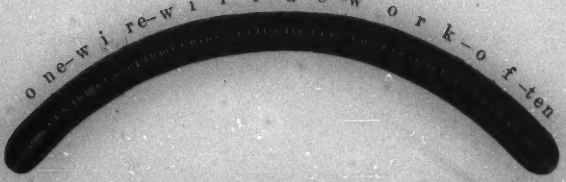


FIG. 12. Polarizing Receiver Record. Message sent at Fort Monroe, Va., Aug. 10, 1896, at the rate of about 1,200 words per minute. This particular message sent in one-half a second. The number of "dots" per second is 337. Continental Code is used.

is given in Fig. 9, where several generators A_1, A_2, A_3, etc., are represented upon the same shaft, and each is connected to a separate brush B_1, B_2, B_3, etc., bearing upon the wheels W_1, W_2, W_3, etc., upon a common shaft and connected to the line. By placing the insulating papers in the proper positions upon the wheels, it becomes possible to transmit in succession, first a current of one frequency and then of another.

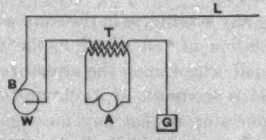


FIG. 8.

If any error is made in laying off the units upon the tape, or if the length of the tape changes in any way after they are accurately laid off, the effect of this error is cumulative from period to period, and although at any particular time the tape might be in phase, sometime later it would not be so, and sparking would occur. This would also be the case if there were any slipping of the tape

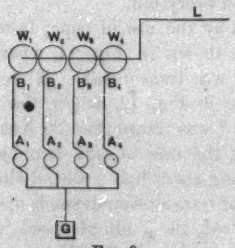


FIG. 9.

around the wheel P. To overcome these difficulties it is only necessary to have holes punched at regular intervals in the tape which engage in pins at corresponding intervals on a wheel made to receive it.

A simple experimental method which does away with the necessity of making pins to feed the tape, is to glue strips of thin paper, seen at o, Fig. 6, having lengths corresponding to the paper

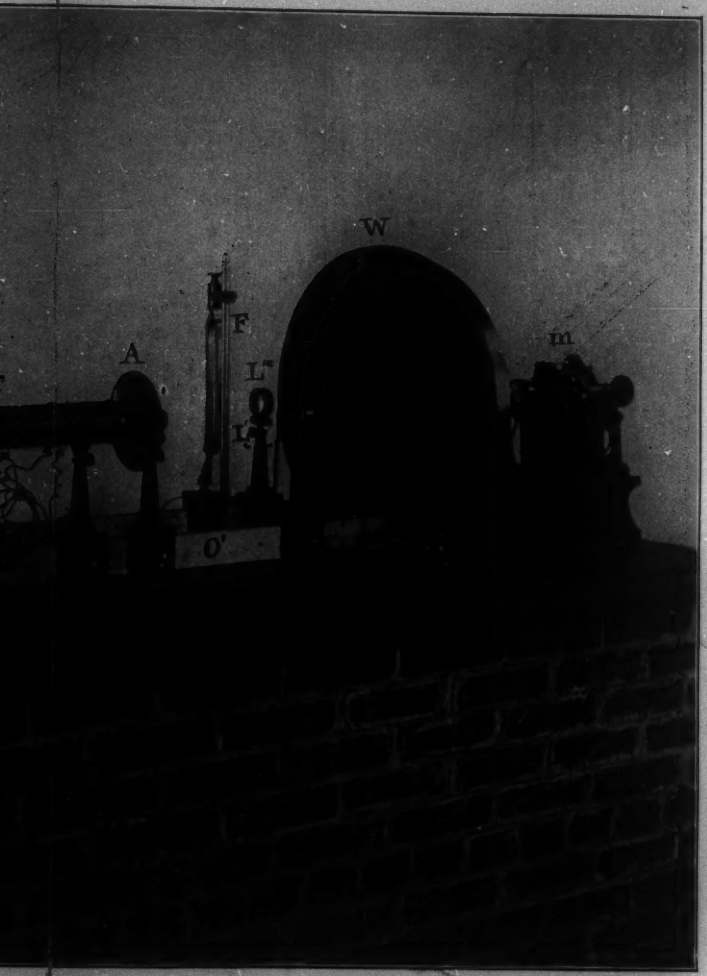
intervals of the tape, that is, one unit for a dot and two units for a dash, upon the circumference of the wheel P, which has a smooth polished metal surface. One brush is continually in contact with the wheel, and the other rides on to and off from these paper strips, making and breaking the circuit at the zero phase of the current. The length of message permitted, is limited by the number of units in the circumference of the wheel, which in the example taken was 184.

Instead of using any gearing, as in the example given, to reduce the speed of revolution of the wheel P, the tape might be run directly from a small wheel upon the armature shaft. The unit on this small wheel is one-tenth of its circumference, if there are ten poles to the generator, so that any message sent by fastening papers upon this wheel would be limited to ten semi-cycles. If a single unit of this small wheel is covered by paper, and the brush adjusted for no sparking, one semi-cycle in every ten will be omitted. A record obtained in this case with the polarizing receiver is shown in the circle at A, Fig. 10, in which each light spot corresponds to one semi-cycle of current, and it is seen that one in every ten is omitted. The record in the circle B of the same figure was obtained by using two units of paper on the same wheel, having two units between them, and shows that two semi-cycles are omitted in every ten.

Records obtained by the use of paper fastened upon the large wheel P, Fig. 6, are shown in Fig. 11, where it is seen that the word "telegraph" was transmitted. A record obtained by the use of tape is shown in Fig. 12, where the sentence "one wire will do work of ten" was transmitted on August 10, 1896. This message was sent at the rate of 337 semi-cycles of current per second, thus requiring about half a second altogether.

Since the speed of transmission depends upon the frequency of the alternating current, the limit of speed is determined by the particular alternator used. In the above example the alternator available was designed to run at a speed of about 1600 revolutions of the armature per minute, corresponding to a frequency of 133, or 266 alternations per second. To increase the speed of transmission, this alternator was run as high as 2400 revolutions per minute, beyond which it was thought dangerous to go. This corresponds to a frequency of about 200 complete cycles or 400 alternations per second. Through the kindness of Dr. M. I. Pupin of Columbia College, a special high-frequency alternator

Fig. 14. The Polarizing I



izing Photo-Chronograph.

was loaned for the purpose of testing this system at higher speeds of transmission. This alternator, shown in Fig. 13, is in fact four alternators upon the same shaft, having 18, 22, 26, and 30 poles respectively. To obtain the highest speed, the 30-pole machine was used, and the transmitting wheel geared to the shaft as with the ten pole alternator. The speed of armature used was 2180 revolutions per minute, corresponding to 1090 semi-cycles per second, or 65,400 per minute, or a frequency of 545. No difficulty was experienced in sending and recording messages at this rapid rate which corresponds to between three and four thousand words per minute.

The Polarizing Receiver.

The statment of the general principles employed in this receiver has previously been given, and it remains to describe the actual form. This instrument was designed for a military chronograph to measure the velocity of projectiles, and is known as the Polarizing Photo-Chronograph[1]. A view of this is shown in Fig. 14.

Without giving a complete description of the instrument, which may be found in the reference cited, it will suffice to describe its essential elements. A sensitive photographic plate 12 x 12 inches square is carried in a metal plate holder, which revolves in the wheel w driven by the motor M. A powerful beam of light from the arc lamp, A, situated upon an inverted T-rail, o′, serving as an optical bench, is condensed by the lens L, and passes through the polarizer P, a Nicol prism, thence through the glass tube T, containing liquid carbon bisulphide, and surrounded by a coil of wire, through the analyzer A, a second Nicol prism. The light received through the analyzer is finally passed through a second lens L′ to focus the beam upon the horizontal radial-slit in front of the moving sensitive plate. In its operation, the analyzer A is rotated until the light is completely extinguished, when no current is passing around the tube T. The coil upon the tube is in circuit with the line from the transmitter, and the closing of the circuit at the transmitter thus sends a current around the tube, and light immediately appears upon the camera slit. This is accomplished instantly upon closing the circuit, without involving the motion of any material thing. Upon breaking the circuit the light imme-

1. "The New Polarizing Photo-Chronograph," Crehore and Squier. John Wiley & Sons, New York, 1897. Chapman and Hall Ltd., London.

diately disappears, and by observing the light come and go, it is easy to read with the eye as rapidly as can be sent by hand. To produce a permanent record it is only necessary to rotate the photographic plate in the wheel w. The time required by the photographic plate to make a clear record, depends largely upon the intensity of the light; but the intensity of light which it is practicable to obtain allows the time of exposure to be much shorter than is required for the purpose of a telegraph receiver. For instance, suppose the width of slit is one millimetre at a distance of 150 millimetres from the centre of revolution, and the plate rotates 1000 times per minute, the velocity of a point on the plate is 1570.8 cms. per second, and the exposure is therefore about .000063 second; for the point crosses the millimetre slit in this time. The above figures are those actually used with the chronograph in measuring the velocity of projectiles inside the bore of a gun and the records obtained are perfectly clear. The rapidity of this receiver is illustrated by stating that as many as seven observations upon a projectile inside the bore of a U. S. 3.2-inch breech-loading field rifle have been recorded in the first 57 centimetres (1 foot 10½ inches) of its travel, and observations as near together as 3.8 cms. (1½ inches) have been obtained. These correspond in time to intervals less than a thousandth of a second, or they bear about the same relation to a second, as a second does to a third of an hour.

In chronography as applied to gunnery, since the agent which operates upon the transmitter circuit is the projectile itself making and breaking the circuit by passing through screens, evidently if the screens are properly placed according to a code, a message could be transmitted to the receiver by a projectile in its flight.

The Chemical Receiver.

In a practical form of receiver, it is an advantage to have the messages received in such form that they are ready for immediate use, and this is the case with the chemical receiver to which reference has already been made.

Through the kindness of Mr. Delany, some of the sensitive paper tape used in his system of machine telegraphy was obtained for experiments with the synchronous transmitter. A simple method of obtaining records of currents with this tape, which is certain in its action and does not involve any special

apparatus, is to place the tape upon a smooth metal surface, which serves as one electrode, and to draw a steel needle, serving as the other electrode, along it guided by the straight edge of a ruler. If a direct current is used, no record appears when the current is in one direction, and it does appear when the current is reversed. If a second needle is substituted for the plate electrode, the record appears on one side of the tape for a direct current and on the other side for the reversed current.

If the two needle electrodes are placed side by side upon the tape, a record will appear at one needle for a direct current, and at the other for the reversed current. Employing the alternating current with the single needle and plate as electrodes, the record shows a regular succession of distinct marks, separated from each other by equal intervals. Each mark exhibits an intensity varying approximately according to the sine curve. Since by this arrangement the current makes its record in one direction only, the result is that alternate semi-cycles of the current are suppressed, and alternate ones are recorded.

By receiving with two needles side by side, all the alternations are recorded, those that were suppressed before now appearing at the second needle. The record then appears as two parallel lines of marks having the maximum intensities in one line opposite the spaces in the other. Using the transmitter as already described with a semi-cycle as a unit in preparing the tape, and receiving in two lines, it is found that some of the marks are omitted in one line and some in the other, and to facilitate translating it is simpler to bring the two lines into coincidence to observe the dots and dashes of the message. A message was then prepared upon the transmitter wheel, using a complete cycle as a unit, instead of a semi-cycle. When received in a single line this message is complete, no matter to which terminal of the circuit the receiving needle is connected, because each unit now contains both a direct and a reversed current, one of which will record.

The same message was then received in two lines, and one line gave the complete message as before, while in the other line there appeared a record for each complete unit in which the current was made. The papers of either the first or the second half of each complete cycle composing the message upon the wheel were next removed, and the message received in two lines as before. The result showed the message complete in one line, while in the other line appeared an uninterrupted succession of marks just as given by the simple alternating current received in one line.

If then an uninterrupted line of marks can be received in one line at the same time that a message is being received in the other, this uninterrupted line can be used for a second message entirely independent of the first. The next experiment accomplished this, and it is now possible to use the same line to send two entirely independent messages in the same direction at the same time at a high rate of speed. The preparation of the transmitting tape to accomplish this, simply requires that the two messages, each prepared with a double unit, shall be displaced a semi-cycle with respect to each other as they pass through the transmitter.

The advantages of duplexing the line, that is, sending two independent messages in opposite directions over one wire at the same time seem more important than those of diplexing the line. An arrangement of circuits which accomplishes this proves to be very simple. Moreover it permits entirely different frequencies to be employed by the transmitters at the two ends of the line, and as before involves no synchronous receiver at either end. By duplexing the line the speed of transmission over a single wire is practically doubled; for example a line that carries 3000 words simplex can carry 6000 words per minute duplex.

It is desirable in many cases to manifold the original copies of the message received, and experiments were made to accomplish this. All that is necessary is to attach to one terminal, instead of a single needle, as many needles as the number of copies desired, having each make its record upon a sensitive surface. The manifolding process evidently applies to either simplex or duplex receiving. Manifold copies of messages may be received in widely different localities at the same time from one and the same transmitter, by connecting the receivers in series or in parallel.

The alternating current is adapted to use with condensers in series with the line where a direct current cannot ordinarily be employed. An experiment was carried out to send a message through a condenser having a capacity of 9.57 microfarads in series with the line, and it was found that the message was transmitted correctly. One object of this experiment was to establish the possibility of using a set of Morse instruments upon the line at the same time that the messages were being transmitted at a high rate of speed by the alternating current. By shunting condensers

around the set of Morse instruments it was found that the operation of either system did not affect the working of the other, so that it becomes possible to use the same high speed line for a complete system of quadruplex telegraphy at the same time. Indeed it seems possible that the present Wheatstone system could be operated over the line in conjunction with the alternating current messages. The experiments with the chemical tape which have been outlined above, together with others not here given, demonstrate the flexibility of a system of intelligence transmission employing the alternating current.

The use of the alternating current as a means of sending intelligence in connection with the fact that a message can be sent through condensers, suggests the possibility of using the principles of electrical resonance employing circuits having natural periods of their own which will pick out and respond to currents from the line having their own frequency.

Although the above illustrations have employed for the most part the Continental code representing a dot and a dash in a particular manner by the omission of certain waves, and the spaces between letters and words by the presence of waves, yet it is evident that this is but one of many combinations which this system permits, and that mentioned above is not to be understood as representing the most desirable one.

A characteristic of the records made by electrolysis is the natural separation of the positive and negative waves of current, which is an advantage in interpretation. This separation is also accomplished in the polarizing receiver by employing two receiver tubes. Instead of setting the polarizer and analyzer for extinction they are so placed that some light is normally transmitted through each tube. The tube coils are so connected that a positive current produces approximate extinction in one tube, and a maximum transmission of light through the other. A negative current transmits a maximum of light through the first tube, and produces approximate extinction in the second. An alternating current therefore causes a record of the positive waves through one tube, and the negative waves through the other, and thus accomplishes all in this respect that the chemical receiver does.

The Line.

It is generally understood that the line limits the speed of telegraphy. The limit is usually reached because of the dis-

tributed electrostatic capacity of the line rather than its resistance. The influence of the distributed capacity is to change the form of the wave as well as reduce its amplitude. With a given length of line having a certain static capacity, there exist limits to the speed obtainable with any given set of instruments which would be a difficult mathematical problem to predetermine. The difficulty in making this calculation is in the influence exerted by the particular instruments used. With different instruments the upper limit of speed is very different with the same line. It therefore seems that the only way to determine this question is by submitting the system to actual trial over a long line.

In order to test this system over as long a line as was available, the land telegraph and telephone lines upon the military reservation at Fort Monroe were joined in series, making about thirteen miles of iron wire having a resistance of 320 ohms. Not only was no difficulty experienced in transmitting and receiving messages over this line, but resistance was introduced making about 1,500 ohms total including the polarizing receiver coil of 390 ohms. This trial was at a frequency of about 200 complete periods per second. With the chemical receiver a coil of 10,900 ohms was used in the laboratory and the record was plainly received at a frequency of about 545 complete periods per second.

Since the polarizing receiver gave indications showing the approximate strength of the varying currents by the intensity of the light upon the plate, it was used to study the effects upon the currents of arbitrarily introducing capacity and inductance in series into the line, especially the effect upon the make of an alternating current at different points of phase. Fig. 15 shows the general appearance of the simple alternating current with different exposures, at different speeds of the plate and the same frequency of alternation. In Fig. 10 the inner record c is that of a circuit having 390 ohms resistance, 1.03 henrys inductance, and 4.78 microfarads capacity at a frequency of 137. At each make it is observed that the first wave is small, followed by a large one. The record at D is for a similar circuit in all respects except that the capacity is doubled, being 9.57 microfarads. Theoretical curves[1] have been computed for these cases and they are in agreement with the records shown.

The method of neutralizing the effects of the distributed

1. "The New Polarizing Photo-Chronograph."—*Journal of the U. S. Artillery*, Fort Monroe, Va., Nov.–Dec., 1896.

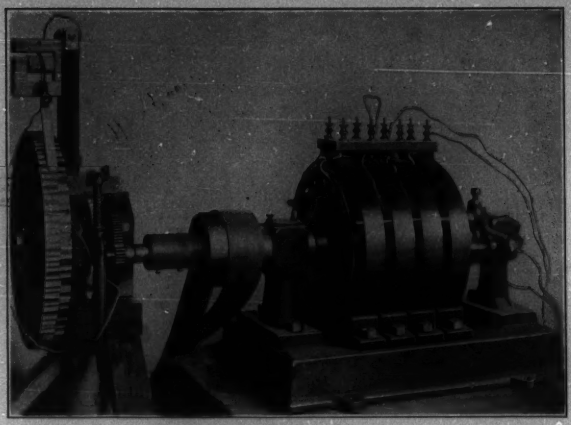
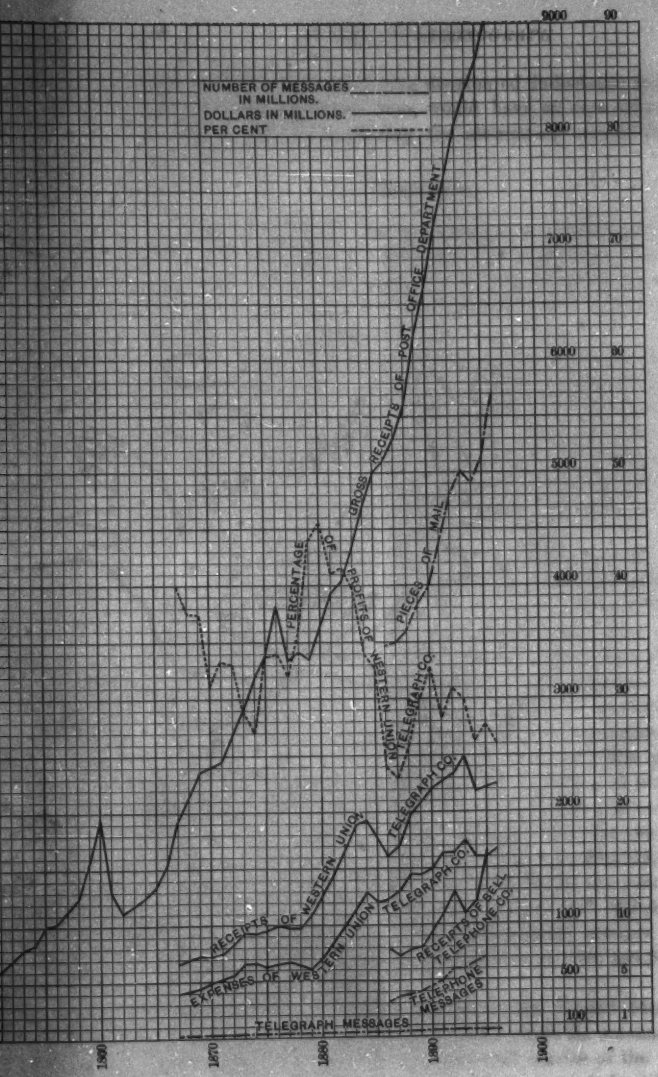


FIG. 13. The Pupin High-Frequency Alternator, attached to Synchronous Transmitter.

FIG. 15. Chronograph Records of the Alternating Current, under varying conditions of circuit and speed of plate.

1790
1800
1810
1820
1830
1840


NUMBER OF MESSAGES IN MILLIONS.
DOLLARS IN MILLIONS.
PER CENT
GROSS RECEIPTS OF POST OFFICE DEPARTMENT
PIECES OF MAIL
PERCENTAGE OF PROFITS OF WESTERN UNION TELEGRAPH CO.
AMOUNT PAID WESTERN UNION TELEGRAPH CO.
RECEIPTS OF WESTERN UNION TELEGRAPH CO.
EXPENSES OF WESTERN UNION TELEGRAPH CO.
RECEIPTS OF BELL TELEPHONE CO.
TELEPHONE MESSAGES
TELEGRAPH MESSAGES
9000
8000
7000
6000
5000
4000
3000
2000
1000
500
100
90
80
70
60
50
40
30
20
10
5
1
1860
1870
1880
1890
1900

capacity of lines by introducing distributed inductance as is now done in some telephone lines, would have an especially useful application in a line employing the alternating current for telegraphy.

Conclusion.

When the extent of the transmission of intelligence at the present time is considered, and the direct influence which this service has upon the development of the world's progress, any proposition which promises to increase its efficiency should be received with consideration.

To better comprehend the volume of this service it is of interest to observe the statistics on the subject. These have been prepared for the United States mail service, the Western Union Telegraph Company, and the American Bell Telephone Company of the United States, and are exhibited in graphical form in Fig. 16. The statistics for the United States Mail service for the last few years were furnished through the courtesy of the Postmaster-General.

It is noticed in general, that there is an increase in all departments of the intelligence transmission service from the earliest dates. The number of pieces of mail sent during 1896 was 5,693,000,000 which is the greatest amount ever sent in a single year. The greatest number of telephone messages on record for a single year is 757,000,000 in 1895. The largest number of telegraph messages was sent in 1893 and amounted to 66,000,000. Thus the greatest number of telegraph messages as compared with telephone messages is in the ratio of 1 to $11\frac{1}{2}$. The greatest number of pieces of mail is in the ratio of 86 to 1 as compared with telegraph messages, or in the ratio of $7\frac{1}{2}$ to 1 as compared with telephone messages. It is also seen that the cost of the mail service of the United States in 1896 was $90,626,000, or about $1.25 per capita. The greatest receipts for any year of the American Bell Telephone Company were in 1895 $16,400,000, about 25 cents per capita, while the greatest receipts of the Western Union Telegraph Company were in 1893 $24,978,000, about 35 cents per capita.

It appears therefore that the people of the United States pay for a telegraph service of about one-eighty-sixth the amount, about one-fourth of that paid for the entire mail service of the United States. It also costs one-and-a-half times as much for telegraph

service as for the telephone service, although the number of telephone messages is about eleven-and-a-half times as great.

A conclusion to be drawn from the above general data seems to be that the people are willing to pay more in proportion for a kind of service like that of the telegraph than any other. From the point of serving the people, as well as from a business standpoint. it appears that improvement in this class of intelligence transmission is at present much to be desired. The present state of the art of telegraphy points to improvements along the line of automatic machine transmission.

It is of interest to inquire what effects a system of telegraphy capable of sending continuously 3,000 words a minute would have on the existing methods. To take a single example of the business between New York and Chicago, where about 40,000 letters are carried daily, it would require but two lines in continuous operation to handle the entire business. At present it takes three days to receive by mail a business reply between New York and Chicago. This transmission by machine telegraphy could be accomplished easily the same day. It is thought that an effect of this would be to increase business transactions to such an extent that the total volume of intelligence transmitted would be augmented, rather than to diminish the business now done by existing methods.

The class of business which such a system would probably at first obtain would be the less urgent telegraph business of greater volume, such as the Associated Press dispatches and newspaper press reports. Among the possibilities is the simultaneous publication of the same newspaper in different parts of the country. For example, in an edition of a daily paper having twelve pages and eight columns per page, making ninety-six columns in all, there are less than 185,000 words. At the rate of 3,000 words per minute it would only require about an hour to transmit the entire contents of the paper. This calculation furthermore assumes that the whole paper is uniformly printed in fine type. It would require a single operator, working by hand and averaging twenty words per minute, over six days of twenty-four hours each to send this amount.

The system proposed is especially adapted to meet the demands of this class of business; for the great flexibility of the alternating current as employed, permits if necessary considerable amounts of power to be transmitted over the line which

may be used for making simultaneous manifold copies of the same dispatches in each of widely separated cities. In this manner each of the several newspaper company subscribers in each city receives the identical service with the minimum delay, since each copy received is an original. Each additional subscriber to this service represents no appreciable expense to the company, since it requires but another receiving needle. Furthermore, the use of the alternating current permits the line to be used quadruplex at very rapid speeds, that is, four entirely different dispatches may be sent over one wire at the same time, two in each direction, and any number of copies of one or all the dispatches may be received independently at the same time.

In addition to the above it is practicable to employ the line for a system of the ordinary quadruplex telegraphy at the same time. In trial experiments in the laboratory, particular instructions were given to the operator of the Morse instrument to observe if possible when messages were being sent by the alternating current, and absolutely no effect was detected.

The objection may be urged, that it is already difficult to handle the business at the present rate of operation of the Wheatstone system, and if the instruments worked faster it could not be handled. This objection is undoubtedly a real one in some cases, and it is partly this fact which indicates that it may be easier to inaugurate new methods than to attempt to adapt the new rapid transmitters to the present methods.

A telegraph office of the future will probably present a different appearance from that which may now be seen in any of the large cities. At present in operating the Wheatstone system in this country, sending to long distances at the rate of 150 to 200 words per minute, both those who prepare the sending tape and those who translate the receiving tape are employés of the telegraph company and are near the sending and receiving instruments. If it requires about ten men to prepare tape, and as many more to translate it for a single instrument operating at 150 words per minute, it will require twenty times this working force for one of the rapid machine transmitters. Evidently changes would be required in the present methods to handle this business.

It is thought that a telegraph company of the future will fulfil a somewhat different function from the present ones. The company will own its wires and rights of way as now, but the tend-

ency of the offices proper will be to transmit and receive letters already prepared rather than to undertake the preparation of the letters as well. The income of the company will be derived from the rent of its lines at a fixed price per minute, or a fixed price per hundred words. The service of the telegraph office then becomes like that of the post office, its duty being to receive and deliver letters already prepared, as the post office does. The difference between the two offices is in the manner in which this is accomplished. The telegraph office becomes a post office which employs an electric current in a copper wire to carry its letters instead of a railroad train. The advantages in point of speed of delivering letters by the former method are apparent. Instead of requiring twenty-four hours to deliver letters between New York and Chicago, it will require but a few hours at most, and make it possible to receive a reply the same day. It is probable that such a system would take more business from the present postal system than any other; for when telegraph letters can be sent at reasonable rates comparable with postage, in a few hours instead of many days, a certain amount of present post office business will be diverted. More than this, when business can be done with greater facility than at present, the total volume of business will undoubtedly be increased, because transactions may take place in a day which formerly required a week.

It would be to the interest of such a company to seek that class of less urgent business now done by correspondence, rather than the class handled by the present telegraph companies, where the highest speed of delivery is expected. If one trunk line becomes established between large business centers, it will draw business from a surrounding area. For instance, if a line were established between New York and Chicago, and a person in Albany desired to communicate with Chicago or points beyond, it would be quicker to send the letter to New York for transmission over the trunk line to Chicago, and then by rail to its destination, than to send directly by rail from Albany. With a few trunk lines in successful operation it would not be long before they would be multiplied.

It is understood that these telegraph letters are sent by mail in envelopes in the usual manner, except that the envelope contains the prepared message ready to be sent through the transmitter, and thus the telegraph office becomes relieved of the preparation of the letters which is not strictly a part of its business. When

the system comes into general use, business offices will have their own perforators, and it will become necessary for the operator to learn the telegraph alphabet as a part of his preparation as a stenographer and typewriter. The three-key perforating machine is comparatively inexpensive, but undoubtedly a machine could be devised at an early date, as an attachment to the present typewriter, for the purpose of perforating letters at the same time that they are being written by the typewriter in the usual way. This could be constructed to operate by the use of electromagnets, and can be attached to a typewriter without interfering in any way with its operation. No extra power would be required, for this can be derived from an electric current which operates the attachment. The writing may be perforated at the present rate of speed of typewriting without the operator having any knowledge of the telegraph alphabet as far as perforating is concerned. This machine will cost more than the three-key perforator, but it would in a short time more than pay for the difference in cost on account of the great gain in speed, and also because it prints a copy of the letter which may be kept on file. Before these perforators are introduced into common use it will be necessary to establish offices in the immediate vicinity of the terminals of the trunk lines, to prepare letters for persons furnishing printed or written copy, as well as to furnish a printed translation when desired of letters received from the central office. The opportunity to obtain a cheaper rate for prepared letters will act as an inducement to those employing a stenographer to add a perforator to their offices.

Concerning the daily correspondence of the large business houses between cities which are the terminals of the trunk lines, it might be an advantage for them to have exclusive use of the line for a certain number of minutes daily at a certain fixed time of day, by subscribing and paying an annual rental to the company. Knowing definitely at what hour the mail would be dispatched daily, it would then be possible for each house to send by messenger its daily mail already prepared for transmission to the general transmission office, where it could be placed in boxes prepared for the subscribers, to be taken out and transmitted when its time arrives. The distribution at the receiving end of the line could be accomplished as now by the regular mail service.

In the limited use of rapid automatic intelligence transmission at present, the sending and receiving records are made upon

prepared paper in the form of tape. In the larger volume of business which is being considered here, it does not seem certain that tape would be the best form for the sending and receiving paper. It would be an advantage to have the letters received upon sheets of paper with the dots and dashes arranged in parallel lines. Besides facilitating the reading, this form would be more convenient for mailing. It would also easily permit reference to any part of the letter at a glance. The amount of paper required by the use of sheet form instead of tape would be reduced, which is an item of importance where such a volume of business is being handled. Sending and receiving from the surface of a cylinder seems entirely practicable.

Another point which must be considered is whether with these systems, the induced currents from neighboring wires along the line or from any other cause will affect the legitimate signals materially, as has been at times the case with the Wheatstone system. In reply to this it can be said that these receivers for telegraphy are not necessarily more sensitive to small currents because they are rapid. On the contrary, they may be made to require as much current as is found desirable to rid them of the effects of outside influences, and at the same time retain the property of quick action in response to currents of the proper magnitude. In this connection it may be said that the utility of a single line wire becomes so great that more attention will be given in the future to the line construction and maintenance. If millions of dollars are invested in the construction of a single railroad, is it not as necessary to make the telegraph lines which carry important and profitable business as perfect in their construction?

The telegraph line of the future will comprise substantial poles carrying a few copper wires worked to their full capacity for transmitting electric signals. The cost of maintenance of such a line when once constructed will be little more than for an ordinary iron wire now used, while its carrying capacity for intelligence at 3,000 words per minute simplex will be about equal to 160 wires used for hand transmission simplex. By duplexing the line, the carrying capacity is doubled and becomes 6,000 words per minute, which is about equal to 160 wires worked duplex, or to 80 wires worked by hand quadruplex.

It is thought that the influence which the inauguration of a telegraph letter system would have upon the existing telegraph

and telephone business would be to increase rather than diminish it. Each of these services has its own special field of usefulness but little affected by the others. A new field would be occupied rather than an old field supplanted. The present telegraph and telephone would still have their natural field of operation, even though the best hopes for a telegraph letter service are realized.

A single line capable of sending 6,000 words per minute between New York and Chicago, becomes a different kind of investment from a long distance telephone line where the number of words per minute with the fastest rate a speaker can talk is very slow in comparison, and the charge is $9 for five minutes' use of this line.

The application under government control of a rapid system of correspondence transmission such as has been outlined, operating in conjunction with the present postal system, by supplementing and relieving their service could hardly fail to prove of benefit to the people of the United States. This comes within the proper duty of the Post Office Department, and would be under the direct control of the Postmaster-General. The simplification in operation and expense which would result from uniting directly with the general post offices of large cities the telegraph letter service would soon be realized by the people and a better service insured.

As a practical means toward ultimately assuming the direct responsibility of this new service, it would probably be easy to secure private companies which would be willing to contract with the Post Office Department to transmit telegraph letters at a fixed rate for a term of years. In this manner the Department could gradually absorb this branch of its business and be relieved of any sudden new responsibility and radical reorganization.

It is not thought that the development of a rapid intelligence transmission service to the extent suggested could be accomplished before many years, nor indeed that the manner or means of this development should closely follow the lines indicated, but that something analogous to this development seems among the possibilities if not the probabilities of the near future.

The persistent efforts of Mr. Delany and the great system which he has developed are well known, and the ideas which he has advanced in regard to the applications of rapid systems are in the main in accordance with those stated herein.

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DOVEJOY, D. R.	Assistant in Electrical Engineering, Columbia University, residence, 222 East 49th St., New York, N. Y.	F. B. Crocker. Wm. A. Anthony. Max Osterberg.
MATHER, EUGENE HOLMES	Superintendent and Electrical Engineer, New Haven Street Railway Co., Exchange Building, New Haven, Conn.	Theo. Stebbins. Geo. F. Sever. Charles Hewitt.
RALSTON, LOUIS C.	Graduate Student, Cornell University, 1170 Madison St., Oakland, Cal.	Fredk. Bedell. Edw. L. Nichols. Harris J. Ryan.
SHAW, HOWARD BURTON	Assistant Professor Electrical Engineering, Missouri State University, Columbia, Mo.	E. H. Hall. C. A. Adams. C. L. Cory.
WELLS, DANA CLEMMER	Assistant in Physics, Columbia University, New York, residence, 109 Willow St., Brooklyn, N. Y.	M. I. Pupin. F. B. Crocker. H. C. Parker.

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